Diffuse interface tumour modelling for personalized neuro-oncology

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Abstract

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In this talk, I will present an original diffuse interface approach based on the integration of clinical, ex-vivo and clinical observations about the GBM mechano-biology characteristics at different scales with mathematical models and methods.

The mathematical model consists in an evolutionary fourth-order partial differential equation with degenerate motility, in which the spreading dynamics of the multiphase tumour is coupled through a growth term with a parabolic equation determining the diffusing oxygen within the brain [3].

Firstly, the model is used to understand the spontaneous budding dynamics observed during in-vitro experiments on a monolayer made of the GBM cell line U87, performed at the FIRC Institute of Molecular Oncology (IFOM). We highlight that this topological transition towards an invasive phenotype is a self-organised, non-equilibrium phenomenon driven by the trade-off of mechanical forces and physical interactions exerted at cell-cell and cell-matrix adhesions. The unstable disorder states of uncontrolled cellular proliferation macroscopically emerge as complex spatiotemporal patterns that evolve statistically correlated by a universal law. Secondly, we develop a computational tool to predict the patient-specific evolution of GBM, and its response to therapy in a clinical study performed at the Neurosurgery unit of the Istituto Neurologico Besta. We collected Magnetic Resonance (MRI) and Diffusion Tensor (DTI) imaging data for a cohort of patients at given times of key clinical interest, from the first diagnosis to the surgical removal and the subsequent radiation therapies. These neuroimaging data allow reconstructing the patient-specific brain geometry in a finite element (FE) virtual environment, that is used for simulating the tumor recurrence pattern after the surgical resection. The results of FE simulations performed on the real geometry of a patient brain quantitatively show how the tumour expansion depends on the local tissue structure. The simulated results are in quantitative agreement with the observed evolution of GBM during growth, recurrence and

response to treatment [1, 2].

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References

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